The finite cell method: a fictitious domain approach applying high-order finite elements

Alexander Düster[1] Stefan Kollmannsberger[2] Dominik Schillinger[3] Ernst Rank[4]

The Finite Element Method (FEM) has become the most frequently applied numerical method in Computational Mechanics. Although the FEM is in a mature state there are still problems where its application is difficult. These problems arise, for example, when considering heterogeneous materials or more generally when discretizing structures which have a very complex geometry. In such cases mesh generation can become very involved. To overcome these problems we propose to apply the Finite Cell Method (FCM) which can be considered as a combination of a fictitious domain method with high-order finite elements. The main idea is to embed the physical domain into an extended domain which can be easily discretized with structured hexahedral meshes. In this way, mesh generation is dramatically simplified and the burden is shifted towards the integration of the stiffness matrices. However, the integration can be performed adaptively in a fully automatic way. During the integration the geometry and varying material properties are taken into account while the discretization error is controlled by adjusting the polynomial degree of the hexahedrals. The proposed method will be illustrated by considering the discretization of problems of solid mechanics in one, two and three dimensions. We present applications of the FCM to the computation of thin-walled structures, the numerical homogenization of heterogeneous materials as well as problems of topology optimization.

References:

[1] B. Szabó, A. Düster, E. Rank. The p-version of the Finite Element Method. *Encyclopedia of Computational Mechanics*, vol. 1:119-139, 2004.
[2] A. Düster, J. Parvizian, Z. Yang, E. Rank. The finite cell method for three-dimensional problems of solid mechanics. *Comput. Methods Appl. Mech. Engrg.*, 197:3768–3782, 2008.
[3] E. Rank, S. Kollmannsberger, Ch. Sorger, A. Düster. Shell Finite Cell Method: A High Order Fictitious Domain Approach for Thin-Walled Structures. *Comput. Methods Appl. Mech. Engrg.*, doi:10.1016/j.cma.2011.06.005, 2011.
[4] J. Parvizian, A. Düster, E. Rank. Topology optimization using the finite cell method. *Optim. Eng.*, DOI 10.1007/s11081-011-9159-x, 2011.

[1] TU Hamburg-Harburg, Numerische Strukturanalyse mit Anwendungen in der Schiffstechnik (M-10), Hamburg, Germany,
alexander.duester@tu-harburg.de

[2] Chair for Computation in Engineering, TU München,
kollmannsberger@bv.tum.de

[3] Chair for Computation in Engineering, TU München,
schillinger@bv.tum.de

[4] Chair for Computation in Engineering, TU München,
rank@bv.tum.de